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# DESCRIPTION

## STAGE UNIT AND ITS MAKING METHOD, AND EXPOSURE APPARATUS AND ITS MAKING METHOD

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### *TECHNICAL FIELD*

The present invention relates to a stage unit and its making method, and an exposure apparatus and its making method, and, more specifically, a stage unit which

10    controls the position of a sample placed on itself and its making method, and an exposure apparatus which is equipped with the stage unit and transfers a predetermined pattern onto a wafer, and its making method.

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### *BACKGROUND ART*

In a lithography process for making a semiconductor device, liquid crystal display device, or the like, an exposure apparatus has been used.  In such an exposure apparatus, patterns formed on a mask or reticle (to be

20    generically referred to as a "reticle" hereinafter) are transferred through a projection optical system onto a substrate such as a wafer or glass plate (to be referred to as a "substrate" or "wafer" hereinafter, as needed) coated with a resist, etc.  As apparatuses of this type,

25    a static exposure type projection exposure apparatus, e.g., a so-called stepper, and a scanning exposure type projection exposure apparatus, e.g., a so-called scanning stepper are mainly used.  Such an exposure apparatus is

equipped with a stage unit, which is movable in two-dimensional directions while holding a wafer, to transfer a pattern formed on a reticle onto a plurality of shot areas on the wafer in turn.

In such a stage unit, the wafer is held on a wafer holder by vacuum chucking, etc. and fixed on a wafer table (movable body) to set the position of the wafer to a exposure position with high accuracy. Such wafer tables have been driven along a mechanical guide surface by a driving unit mechanically in contact with the wafer table and movable. Therefore, stage units have been equipped with X-stage to drive the wafer table in X direction and Y-stage to drive the wafer table together with X-stage in Y direction to move the wafer table on the X-Y plane.

Meanwhile, the development of a stage unit which controls the position of a wafer with high accuracy without being affected by the mechanical accuracy, etc. of a guide surface and performs positioning of the wafer by supporting a flat-plate-like shaped and movable body, on which the wafer is placed above a supporting member, by levitation and driving the movable body in a non-contacting manner to avoid mechanical friction and prolong the life of the stage is in progress. As such stage units, a variable magnetic reluctance driving method in which a linear pulse motor, as in a Sawyer motor, using the variable magnetic reluctance driving method is so structured that two axes are combined with

each other, and a stage unit using a planar motor as a
driving unit (driver) employing a Lorentz
(electromagnetic) force method disclosed in, for example,
Japanese Patent Laid-Open No. 58-175020 and U.S. Patent

5   No. 5,196,745 have been suggested.

Recently, wafers on which patterns are transferred
by an exposure apparatus are being enlarged. Along with
the enlargement of wafers, a wafer table as a table on
which a wafer is placed is also enlarged and necessarily

10   the weight of the wafer table is increased. Therefore it
is necessary to drive the wafer table by a large force to
move the wafer at high speed for the improvement of the
through-put of the exposure apparatus.

Incidentally on driving the wafer table, the wafer

15   table and a mover are moved together as one entity
against a stator using a driving unit comprising the
mover and the stator and on this occasion, a reaction to
the force applied to the mover is induced in the stator.
As a consequence, a vibration occurs and is transmitted

20   to other members when the mover is mechanically connected
with other members of the exposure apparatus, and then
inflicts a bad effect on exposure accuracy. For example,
when the mover is mechanically connected with a
supporting member with respect to a projection optical

25   system of the exposure apparatus, the projection optical
system will vibrate and cause the degradation of the
exposure accuracy.

Such a bad effect to the exposure accuracy generally

becomes severer along with the increase of drive force of the mover. Therefore along with the enlargement of wafers, the mover is driven by a large force to move the wafer at high speed for the improvement of the through-

5 put and the exposure accuracy will be degraded remarkably. That is, along with the enlargement of wafers it is getting difficult to improve both the through-put and the exposure accuracy.

The present invention has been made in view of the

10 condition above. A first object of the present invention is to provide a stage unit that can move a placed sample at high speed and perform accurate positioning.

Also, a second object of the present invention is to provide an exposure apparatus that can improve both the

15 through-put and the exposure accuracy by high speed movement of a substrate and highly accurate positioning.


## DISCLOSURE OF INVENTION

From a first aspect, the present invention is a

20 stage unit that is equipped with a driving unit (50) including a mover (51) and a stator (60); and a reaction canceling mechanism (45X1, 45X2, 45Y1, 45Y2, 63C1, 63C2, 63C3, 63C4, 19, 22) to apply the stator (60) a force canceling a reaction acting on the stator (60) by

25 electromagnetic interaction. This stage unit is referred to as a "first stage unit of the present invention" hereafter.

According to the present invention, the reaction

canceling mechanism generates a force to cancel the reaction acting on the stator by using electromagnetic interaction excellent in controllability and linearity and applies it to the stator, thereby accurately

5   canceling the reaction acting on the stator. Accordingly, even with the increase of the drive force of the mover, the vibration of the stator is prevented and the stage unit is capable of high accurate positioning while moving a sample placed on itself.

10       In the first stage unit of the present invention, if the reaction canceling mechanism can apply to any arbitrary point of the stator a force having an arbitrary magnitude and an arbitrary direction, the reaction canceling mechanism may generate one kind of force and

15   apply it to an appropriate point (for example, applying a force having the same magnitude as the reaction and opposite direction to the point of reaction application of the stator) to cancel a reaction caused by driving the mover translationally. However, when the stator is

20   rotationally driven or the point of the stator to which the reaction canceling mechanism applies the force is fixed, it is generally impossible to cancel the reaction just by giving the stator one kind of force.

        Therefore, in the first stage unit of the present

25   invention, it is preferred for the reaction canceling mechanism to generate a force to act on at least two points of the stator and cancel the reaction as a whole. In this case, if the reaction canceling mechanism can

apply forces having an arbitrary magnitude and an arbitrary direction to at least two fixed points of the stator, the reaction acting on the stator by a translational driving, a rotational driving or the

5    combination of the both can be canceled. Especially, when the reaction acting on the stator is a force along a predetermined plane, the reaction can be canceled by applying two kinds of forces being along the predetermined plane and having magnitude and direction

10    corresponding to the reaction.

The aforementioned case shows a case where the reaction canceling mechanism can apply the force having an arbitrary magnitude and an arbitrary direction to the stator. However, in a case where the points of the

15    stator to which the reaction canceling mechanism applies the forces are fixed and the direction of the force applied to each point is predetermined, the reaction generally can not be canceled just by applying two kinds of forces to the stator. In such a case, the reaction

20    canceling mechanism generates forces having respective predetermined directions, which cancel the reaction as a whole, and applies them to at least three points of the stator, thereby being able to cancel the reaction acting on the stator by a translational driving, a rotational

25    driving or the combination of the both. Especially, if the reaction acting on the stator is a force along a predetermined plane, the reaction can be canceled by the reaction canceling mechanism applying three kinds of

forces having magnitudes corresponding to the reaction
and predetermined directions not parallel to each other,
which are applied on three fixed points of the stator and
are along the predetermined plane.

5      In the first stage unit of the present invention,
the driving unit can be so structured that the drive
force of the mover is generated by electromagnetic
interaction.  In such a case, as described above, the
reaction acting on the stator on driving the mover can be
10    accurately identified before driving the mover by
generating the drive force for the mover by using
electromagnetic interaction excellent in controllability
and linearity.  Therefore, the reaction acting on the
stator can be canceled with high response-speed and
15    accuracy by the reaction canceling mechanism applying a
force to cancel the reaction acting on the stator to the
stator in a manner like feed-forward simultaneously with
driving the mover.  That is, the stator appears to be
free from the reaction.

20    The driving unit which generates the drive force for
the mover by electromagnetic interaction is so structured
that, for example, the stator has an armature unit (61)
including a plurality of armature coils (63), which are
arranged in the shape of a matrix in a predetermined
25    plane and have current paths almost parallel to the
predetermined plane, and the mover has a driving magnetic
pole unit (51) to generate a magnetic flux having a
direction crossing the predetermined plane.

In the first stage unit of the present invention equipped with this driving unit, the reaction canceling mechanism is so structured that reaction canceling magnetic pole units (45X1, 45X2, 45Y1, 45Y2) to generate

5    a magnetic flux having a direction crossing the current paths of armature coils (63C1, 63C2, 63C3, 63C4) disposed on four corners of the armature unit and a control system (19, 22) controls the direction and amplitude of currents supplied for the armature coils disposed on four corners

10    of the armature unit are equipped. In this case, by the control system controlling the direction and amplitude of currents supplied for the armature coils disposed on four corners of the armature unit and the electromagnetic interaction between magnetic field induced by the

15    magnetic pole units and the currents flowing in the armature coils disposed on four corners of the armature unit, the force canceling the reaction is applied to the stator along the same predetermined plane as the plane that the reaction is along. Accordingly, four forces

20    along a predetermined plane, which have respective predetermined directions in the four fixed points of the stator and have magnitudes corresponding to the reaction, are applied with good controllability and the reaction can be canceled very accurately.

25    Incidentally, when applying to the stator the force to cancel the reaction acting on the stator on driving the mover, the reaction eventually comes to act on the reaction canceling magnetic pole units. It is preferred

that the reaction canceling magnetic pole units and the stator are mechanically independent from each other to prevent the vibration from transmitting to the stator by the reaction acting on the reaction canceling magnetic

5   pole units.

The reaction canceling magnetic pole units can be structured so that forces perpendicular to each other in neighboring corners of the armature unit are generated. In such a case, the force to cancel the reaction acting

10   on the stator can be easily calculated.

From a second aspect, the present invention is a method of making a stage unit comprising a process to provide a driving unit (50) including the mover (51) and the stator (60); and a process to provide the reaction

15   canceling mechanism (45X1, 45X2, 45Y1, 45Y2, 63C1, 63C2, 63C3, 63C4, 19, 22) to apply the force canceling the reaction, which is induced by the driving of the mover (51) and is acting on the stator, to the stator (60) by the electromagnetic interaction. According to this, by

20   providing the driving unit and the reaction canceling mechanism and combining these and other elements mechanically, electrically, and optically as the need arises, the first stage unit of the present invention is made.

25   From a third aspect, the present invention comprises the armature unit (61) including a plurality of  armature coils (63), which are arranged in the shape of a matrix on the predetermined plane and whose current paths are

almost parallel to the predetermined plane; the magnetic

pole unit (51) having a plurality of magnets (55, 56, 57N,

57S, 58N, 58S) magnetized in directions not perpendicular

to the predetermined plane and two-dimensionally

5    generating an alternating magnetic field with a period of

4P/3 in two axis-directions perpendicular to each other

practically without generating any magnetic field in an

area opposite to the armature unit (61); and a current

driving unit (22) to move the magnetic pole unit

10   relatively to the armature unit in a plane parallel to

the predetermined plane by supplying currents to the

armature coils (63) respectively.  Hereinafter, this

stage unit is referred to as a "second stage unit of the

present invention".

15       According to this, in making a steady magnetic

circuit having a low magnetic resistance, the magnetic

pole unit is composed only of the aforementioned magnets

without using other magnetic members than the magnets,

thereby realizing the light weight of the mover.

20   Accordingly, the driving force of the mover can be

reduced and the reaction acting on the stator can be

reduced, thereby the vibration of the stator can be

decreased and highly accurate positioning can be realized

while moving a placed sample at a high speed.

25       The second stage unit of the present invention can

further comprise a magnetic member (62) supporting the

armature coils in a side opposite to the magnetic pole

unit.  In such a case, a magnetic circuit is structured

through the magnetic pole unit and the magnetic member, thereby a steady magnetic circuit having a low magnetic resistance can be structured. Therefore, a magnetic flux having high flux density can be generated in the positions of the armature coils. Incidentally, as a material for the magnetic member, one having high electric resistance, high saturation magnetic flux density, low magnetic hysteresis, and low coercive force is preferred.

10      Also, the second stage unit of the present invention can further comprise a flat-plate-like shaped member (68) disposed between the armature unit and the magnetic pole unit and made of a non-magnetic and non-conductive material. In such a case, when structuring the magnetic

15    pole unit so that it is not contacting the armature unit by an air-bearing system, an air blew out of the magnetic pole unit is blew on the flat-plate-like shaped member, thereby the magnetic pole unit and the flat-plate-like shaped member, eventually the armature unit can be non-

20    contacting each other. Furthermore, because the flat-plate-like shaped is non-magnetic and non-conductive, the magnetic flux generated by the magnetic pole unit is not affected. Accordingly, an easy implementation of relative move at high speed by a small driving force is

25    possible. Incidentally, as a non-magnetic material means a material having magnetic permeability small enough compared with a magnetic material such as iron, etc. and almost equal to that of the air. Furthermore, a non-

conductive material means a material having conductance small enough compared with a conductive material such as copper, etc. and almost equal to that of the air.

Furthermore, the second stage unit of the present
5  invention can be so structured that the current driving unit supplies currents for the respective armature coils independently.  In such a case, the value and direction of each of currents supplied for the respective armature coils can be controlled independently, thereby the
10  magnetic pole unit and the armature unit can be relatively moved in a predetermined direction.

Furthermore, the second stage unit of the present invention comprises a position detection system (31) to detect the positional relation between the magnetic pole
15  unit (51) and the armature unit (61); and a control unit (controller) (20) to control at least one of the value and direction of each of currents supplied for the respective armature coils (63) via the current driving unit (22) based on detection results by a position detection (31).
20  In such a case, the relative position and the relative speed between the magnetic pole unit and the armature unit can be controlled by controlling the value and direction of the respective currents flowing in the armature coils based on position information (speed
25  information) obtained by the position detection system with respect to the magnetic pole unit and the armature unit.

The second stage unit comprising the position

detection system and the control unit described above is so structured that the control unit selectively supplies currents for the armature coils opposite with the magnetic pole unit.  In such a case, with not supplying

5    currents for armature coils in which no or just weak Lorentz force is induced, efficient current supply is possible and current dissipation can be reduced while maintaining the driving force.

From a fourth aspect, the present invention is a

10   making method comprising a process to provide the armature unit (61) including a plurality of armature coils (63) having a current path almost parallel to the predetermined plane and being arranged in the shape of a matrix on the predetermined plane; a process providing

15   the magnetic pole unit (51) having a plurality of magnets (55, 56, 57N, 57S, 58N, 58S) magnetized in directions not perpendicular to the predetermined plane and two-dimensionally generating an alternating magnetic field with a period of 4P/3 in two axis-directions

20   perpendicular to each other practically without generating any magnetic field in an area opposite to the armature unit; and a process providing a current driving unit (22) to move the magnetic pole unit (51) relatively to the armature unit (61)  in a plane parallel to the

25   predetermined plane by supplying currents for the armature coils (63) respectively.  According to this, by providing the armature unit, the magnetic pole unit and the driving unit, and then combining and adjusting these

and other elements mechanically, electrically, and optically as the need arises, the second stage unit of the present invention is made.

In this case, furthermore, it is possible to include a process to provide the position detection system (31) to detect a positional relation between the magnetic pole unit (51) and the armature unit (61); and a process to provide the control unit (20) to control at least one of the value and direction of each of currents supplied for the respective armature coils (63) through the current driving unit (22) based on detection results by a position detection (31). In such a case, a stage unit, in which the relative position and the relative speed between the magnetic pole unit and the armature unit can be controlled, can be made.

Incidentally, needless to say, both the first stage unit and the second stage unit can be applied to one stage unit. In such a case, the reaction can be accurately canceled as well as reducing the reaction acting on the stator by, for example, decreasing the driving force of the magnetic pole unit as a mover.

Furthermore, by applying both the making method of the first stage unit and that of the second stage unit to the making of one stage unit, a stage unit to which both the first stage unit and the second stage unit are applied can be made.

From a fifth aspect, out of exposure apparatuses that expose the substrate by irradiating an energy beam

and transfer a predetermined pattern onto the substrate, the present invention is an exposure apparatus having a feature of comprising a stage unit (30) as a position control unit to control the position of the substrate.

5      According to this, by exposing the substrate placed on the stage unit of the present invention, a move at a high speed and highly accurate control of position of the substrate are possible, and both the through-put and the accuracy of exposure can be improved.

10      From a sixth aspect, out of making methods of an exposure apparatus that exposes a substrate (W) by irradiating an energy beam and transfers an predetermined pattern onto the substrate (W), the present invention is a method of making the stage unit (30) by providing the

15   driving unit (50) including the mover (51) and the stator (60), and the reaction canceling mechanism (45X1, 45X2, 45Y1, 45Y2, 63C1, 63C2, 63C3, 63C4, 19, 22) to apply the force canceling the reaction, which is induced by the driving of the mover (51) and is acting on the stator

20   (60), to the stator (60) by the electromagnetic interaction; and an exposure apparatus making method including the disposing of the stage unit (30) as a position control apparatus to control the position of the substrate. According to this, an exposure unit

25   comprising the first stage unit of the present invention as a position control apparatus to control the position of the substrate is made.

     From a seventh aspect, out of making methods of an

exposure apparatus that exposes a substrate (W) by irradiating an energy beam and transfers an predetermined pattern onto the substrate (W), the present invention is a method of making the stage unit (30) by providing the

5  armature unit (61) including a plurality of armature coils (63) that are arranged in the shape of a matrix on the predetermined plane and have current paths almost parallel to the predetermined plane, the magnetic pole unit (51) having a plurality of magnets (55, 56, 57N, 57S,

10  58N, 58S) magnetized in directions not perpendicular to the predetermined plane and two-dimensionally generating an alternating magnetic field with a period of 4P/3 in two axis-directions perpendicular to each other, between the armature coils (63) and itself, practically without

15  generating any magnetic field in an area opposite to the armature unit (61), and the current driving unit (22) to move the magnetic pole unit (51) relatively to the armature unit (61) in a plane parallel to the predetermined plane by supplying currents for the

20  armature coils (63) respectively; and an exposure apparatus making method including the disposing of the stage unit (30) as a position control apparatus to control the position of the substrate. According to this, an exposure unit comprising the second stage unit of the

25  present invention as a position control apparatus to control the position of the substrate is made.

Incidentally, needless to say, an exposure apparatus can be structured which comprises a stage unit, to which

both the first stage unit and the second stage unit of the present invention are applied, as a position control apparatus to control the position of the substrate. In such a case, both the through-put and the accuracy of

5  exposure can be improved.

Furthermore, by applying both the making method of an exposure apparatus comprising the first stage unit and the making method of an exposure apparatus comprising the second stage unit of the present invention to the making

10  of one exposure apparatus, an exposure apparatus can be made which comprises a stage unit to which both the first stage unit and the second stage unit of the present invention are applied.

15              **_BRIEF DESCRIPTION OF THE DRAWINGS_**

Fig. 1 is a diagram showing the schematic arrangement of an exposure apparatus according to an embodiment of the present invention;

Figs. 2 is a perspective diagram showing an

20  arrangement around the stage unit of the exposure apparatus of Fig. 1;

Figs. 3 is a diagram showing the arrangement of the magnetic pole unit;

Figs. 4(A) to 4(H) are diagrams (No.1) showing the

25  arrangements of permanent magnet modules composing the magnetic pole unit and the shapes of permanent magnets;

Fig. 5(A) to 5(D) are diagrams (No.2) showing the arrangements of permanent magnet modules composing the

magnetic pole unit and the shapes of permanent magnets;

Fig. 6 (A) to 6(C) are diagrams illustrating the arrangement of magnetic poles in the magnetic pole unit;

Figs. 7 is a diagram showing an arrangement around the stator;

Figs. 8 (A) and 8(B) are diagrams showing the arrangement of a flat-plate-like shaped coil module;

Figs. 9 (A) and 9(B) are diagrams showing the arrangement of a reaction canceling magnetic pole unit;

Fig. 10 is a diagram illustrating the principle of the scanning-exposure of the exposure apparatus of Fig. 1;

Figs. 11 (A) and 11(B) are diagrams illustrating magnetic circuits with respect to the magnetic pole unit;

Figs. 12 (A) and 12(B) are diagrams illustrating forces acting on armature coils upon the drive of the mover;

Figs. 13 (A) to 13(C) are diagrams illustrating a magnetic flux density around an armature coil, a supply current to the armature coil, and a force acting on an armature coil upon the drive of the mover;

Figs. 14 (A) and 14(B) are diagrams illustrating a magnetic circuit with respect to a reaction canceling magnetic pole unit;

Figs. 15 (A) and 15(B) are diagrams illustrating forces acting on an armature coil upon the canceling of the reaction;

Figs. 16 is a diagram illustrating the action of

reaction canceling;

Figs. 17 is a diagram illustrating a variation of the present invention;

5    ### *Best Mode for Carrying out the Invention*

An embodiment of the present invention will be described below with reference to Fig. 1 to Fig. 16. Fig. 1 shows the entire configuration of an exposure apparatus 100 according to the embodiment of the present invention.

10    Incidentally, this exposure apparatus 100 is an exposure apparatus based on the so-called step and scan exposure method.

The exposure apparatus 100 comprises: an illumination system 10; a reticle stage RST holding a

15    reticle R as a mask; a projection optical system PL; a stage unit 30 to drive a wafer W as a substrate in X-Y two-dimensional directions on an X-Y plane (including rotational moves around Z axis ; and a control system for controlling these elements.

20    The illumination system 10 is comprised of a light source, an illuminance uniformization optical system constituted by a fly-eye lens and the like, a relay lens, a variable ND filter, a reticle blind, a dichroic mirror, and the like (none of which are shown). The arrangement

25    of such an illumination system is disclosed in, for example, Japanese Patent Laid-Open No. 10-112433. This illumination system 10 illuminates a slit-like (in the shape of rectangle or circular arc) illumination area

portion IRA (refer to Fig. 10) defined by the reticle blind above the reticle R, on which a circuit pattern and the like are drawn, with illumination light IL and with almost uniform illuminance.

5    The reticle R is fixed on the reticle stage RST by, for example, vacuum chucking.  In order to position the reticle R, the reticle stage RST can be finely driven within the X-Y plane perpendicular to the optical axis of the illumination system 10 (which coincides with an

10   optical axis AX of the projection optical system PL (to be described later)) by a reticle stage driving unit (not shown) formed by a magnetic levitation type two-dimensional linear actuator, and can also be driven in a predetermined scanning direction (the Y direction in

15   this case) at a designated scanning velocity.  In this embodiment, the above magnetic levitation type two-dimensional linear actuator includes a Z drive coil in addition to X and Y drive coils, and hence can finely drive the reticle stage RST in the Z direction as well.

20   The stator of the two-dimensional linear actuator described above is supported by a reaction frame (not shown) disposed independently from a supporting member 40. Therefore, the reaction acting on the stator of the two-dimensional linear actuator is transmitted through

25   the reaction frame to the ground (floor) but not to the supporting member 40 on driving the reticle stage RST. Such transmission through a reaction frame to the ground is disclosed in, for example, the U.S. Patent Application

No. 08/416,558. The disclosure in the United States
Patent Application described above is fully incorporated
by reference herein as long as the national laws in
designated states or elected states, to which this
5    international application is applied, permit.

The position of the reticle stage RST within a stage
moving plane is detected all the time through a movable
mirror 15 by a reticle interferometer 16 fixed on the
supporting member 40 as a position detection unit with a
10   resolution of, for example, 0.5 to 1 nm.   Positional
information of the reticle stage RST from the reticle
interferometer 16 is sent to a stage control system 19
and the stage control system 19 drives the reticle stage
RST via a reticle stage driving portion (not shown) based
15   on the positional information of the reticle stage RST.
Incidentally, in practice, a movable mirror having a
reflection surface perpendicular to the scanning
direction (Y axis direction) and a movable mirror having
a reflection surface perpendicular to the non-scanning
20   direction (X axis direction) are attached on the reticle
stage RST and the reticle interferometer 16 has one axis
in the scanning direction and two axes in non-scanning
direction.   In Fig. 1, however, the movable mirror 15 and
the reticle interferometer 16 are representatively shown.
25       The projection optical system PL is arranged under
the reticle stage ST as shown in Fig. 1, and the optical
axis AX (coinciding with the optical axis IX of the
illumination optical system) is set as the Z-axis

direction.   In this embodiment, a refraction optical system is employed which is structured of a plurality of lenses disposed along the optical axis AX at a predetermined interval, so as to make a double

5   telecentric optical arrangement.   The projection optical system PL is a reduction optical system having a predetermined magnification of, for example, 1/5 (or 1/4). Therefore, when the illuminating light emitted by the illumination system 10 illuminates the illumination area

10   IAR of the reticle R, a reduced image (a partially inverted image) of a circuit pattern of the reticle R is formed on an exposure area IA on a wafer W, which is conjugate with the illumination area IRA (refer to Fig. 10).   The image is formed on the wafer W, which has a

15   photoresist coated on its surface, through the projection optical system PL by the illumination light that passes through the reticle R.

The stage unit 30 comprises: a base 21; a substrate table 18 supported by air levitation with an air slider

20   (to be described later) above the upper surface of this base 21 via a clearance of several microns or so; and a driving unit 50 for driving the substrate table 18 within the X-Y plane in two-dimensional directions.

A wafer holder 25 is fixed on the substrate table 18

25   and a wafer W is held by the wafer holder 25 using, for example, vacuum chucking.

Furthermore, a movable mirror 27 to reflect a laser beam from a wafer laser interferometer (referred to as

"wafer interferometer" hereafter) 31, which is fixed on the supporting member 40 as a position detection unit, is fixed on the substrate table 18. The position of the wafer W in X-Y plane is detected all the time by the

5 externally placed wafer-interferometer 31 with a resolution of 0.5 to 1 nm or so. As shown in Fig. 1, the wafer-interferometer 31 is attached on the supporting member 40. Positional information (or speed information) of the wafer is sent to the stage control system 19 and

10 then to the main control unit 20, and the stage control system 19 controls the driving unit 50 via the current driving unit 22 in accordance with instructions from the main control unit 20 and based on the Positional information (or speed information). Incidentally, in

15 practice as shown in Fig. 2, a movable mirror 27Y having a reflection surface perpendicular to the scanning direction (Y axis direction) and a movable mirror 27X having a reflection surface perpendicular to the non-scanning direction (X axis direction) are attached on the

20 substrate table 18 and the wafer interferometer 31 has one axis in the scanning direction and two axes in the non-scanning direction. In Fig. 1, however, the movable mirror 27 and the wafer interferometer 31 are representatively shown.

25 The reticle stage RST (excluding the not shown stator) described above, the projection optical system, the base 21, the reticle interferometer 16, and the wafer interferometer 31 are held by the supporting member 40

and mechanically combined.

Furthermore, the exposure apparatus of the present embodiment 100 comprises reaction canceling magnetic pole units 45X, 45Y to generate a magnetic field for applying

5   a force canceling a reaction acting on the stator 60 of the driving unit 50 to the stator 60. Incidentally, the reaction canceling magnetic pole unit 45X generates a magnetic field to cancel X-component of the reaction acting on the stator 60 and the reaction canceling

10  magnetic pole unit 45Y generates a magnetic field to cancel Y-component of the reaction acting on the stator 60. The structure of the reaction canceling magnetic pole units 45X, 45Y will be described later. Incidentally, in practice, as shown in Fig. 2, the

15  reaction canceling magnetic pole units 45X1, 45X2 are disposed in the respective corners of two corners in a first diagonal relation out of the four corners of the stator. In Fig. 1, however, just the reaction canceling magnetic pole units 45X is illustrated representing these.

20  And the reaction canceling magnetic pole units 45Y1, 45Y2 are disposed in the respective corners of two corners in a second diagonal relation out of the four corners of the stator. In Fig. 1, however, just the reaction canceling magnetic pole units 45Y is illustrated representing these.

25      On the substrate table 18, a fiducial mark plate (not shown) is fixed on which various kinds of fiducial marks for the measurement of base lines to measure the distance between the detection center of an alignment-

detection system (not shown) of the off-axis method and the optical axis of the projection optical system PL are formed.

Furthermore, the exposure apparatus 100, shown in Fig. 1, comprises a multiple focal position detection system which is one of focus detecting systems (or focal point detecting systems) based on the oblique incidence method. The system is for detecting the position in Z direction (the direction of optical axis AX) of the area including the exposure area IA on the wafer W's surface and the neighborhood. This multiple focal position detection system comprises an illumination optical system (not shown) and a light receiving system (not shown). The detailed configuration of the multiple focal position detection system is disclosed in, for example, Japanese Patent Laid-Open No. 6-283403 and its corresponding U.S. Patent No. 5,448,332. The disclosure of this multiple focal position detection system in the United States Patent described above is fully incorporated by reference herein as long as the national laws in designated states or elected states, to which this international application is applied, permit.

As the driving unit 50, a planar motor composed of the stator 60 embedded in the upper portion of the base 21 and a mover 51 fixed to the bottom portion (the surface side opposite with the base) of the substrate table 18, is used. In the following description, the driving unit 50 will be referred to as the planar motor

50 for the sake of convenience.  The detailed description
of the structure of this planar motor 50 and the
structure of the reaction canceling mechanism to cancel
the reaction acting on the stator will follow.

5      The mover 51 is, in the present embodiment, so
structured that permanent magnet modules (52N, 52S, 53N,
53S, 54N, 54S) and permanent magnets 55, 56, as shown in
Fig. 3, are arranged in a shape of mesh as a whole in a
planar view.  In the following description, this mover is
10     also referred to as a driving magnetic pole unit 51 for
the sake of convenience.  Furthermore, the permanent
magnet modules 52N, 53N, 54N are magnets having the
surface opposite with the stator 60 practically
magnetized as N pole, and the permanent magnet modules
15     52S, 53S, 54S are magnets having the surface opposite to
the stator 60 practically magnetized as S pole.
Incidentally, in Fig. 3, hollow portions are surrounded
by thick lines and to show the numbers of the components
except for the left end and the right end of the mesh-
20     like structure, those numbers are written on the
respective components omitting leader lines.

In the driving magnetic pole unit 51, the permanent
magnet modules 52N, 52S are arranged alternately in the
shape of a matrix in the center of the mesh-like
25     structure described above.  Furthermore, the permanent
magnet modules 53N, 53S are arranged alternately on the
four corners of the mesh-like structure and the permanent
magnet modules 54N, 54S are arranged alternately on each

end, and between the permanent magnet module 52N and the permanent magnet module 52S, between the permanent magnet module 52N and the permanent magnet module 54S, and between the permanent magnet module 52S and the permanent

5    magnet module 54N, a permanent magnet 55 is placed respectively, and between the permanent magnet module 53N and the permanent magnet module 54S, between the permanent magnet module 53S and the permanent magnet module 54N, and between the permanent magnet module 54N

10   and the permanent magnet module 54S, a permanent magnet 56 is placed respectively.

Incidentally, as shown in Fig. 3, it is when an odd number of the permanent magnet modules 52N, 52S are placed both in the lateral direction (X axis direction)

15   and longitudinal direction (Y axis direction) that the permanent magnet modules 53N, 53S are alternately arranged on the four corners of the mesh-like structure. When an even number of the permanent magnet modules 52N, 52S are placed in the lateral direction, the permanent

20   magnet modules 53N's or 53S's are placed on the both of the two corners in the lateral direction, and when an even number of the permanent magnet modules 52N, 52S are placed in the longitudinal direction, the permanent magnet modules 53N's or 53S's are placed on the both of

25   the two corners in the longitudinal direction. Accordingly, when an even number of the permanent magnet modules 52N, 52S are placed both in the lateral direction and the longitudinal direction, the permanent magnet

modules 53N's or 53S's are placed on the all four corners
of the mesh-like structure.

Furthermore, in the present embodiment, the
permanent magnet modules 52N, 52S are arranged in the

5      shape of a square matrix.

The permanent magnet module 52N, as shown in Fig.
4(A), has a square bottom surface with P/3 as the length
of one side, takes H as the height of the periphery and
has such a shape that a concave is formed in the center

10     of the upper surface as a whole.  This permanent magnet
module 52N comprises four of permanent magnet 57N having
the shape of a wedge shown in Fig. 4(B).  Such a
permanent magnet 57N has a surface becoming the periphery
of the permanent magnet module 52N to be S pole and

15     another surface becoming the center of the permanent
magnet module 52N to be N pole when assembled.

The permanent magnet module 52S is, as shown in Fig.
4(C), in the same shape as the permanent magnet module
52N.  This permanent magnet module 52S comprises four of

20     permanent magnet 57S having  the shape of a wedge shown in
Fig. 4(D).  Such a permanent magnet 57S has a surface
becoming the periphery of the permanent magnet module 52S
to be N pole and another surface becoming the center of
the permanent magnet module 52S to be S pole when

25     assembled.

The permanent magnet module 53N, as shown in Fig.
4(E), has a square bottom surface with P/6 as the length
of one side, takes H as the height, and has such a shape

that the permanent magnet module 52N is divided into four

equal parts by two planes respectively parallel to two

side-surfaces of the permanent magnet module 52N, which

are perpendicular to each other.  This permanent magnet

5    module 53N comprises two of permanent magnet 58N having

the shape of a wedge shown in Fig. 4(F).  Such a

permanent magnet 58N has such a shape that the permanent

magnet 57N is divided into two equal parts by a plane

perpendicular to its bottom surface and S pole surface.

10       The permanent magnet module 53S, as shown in Fig.

4(G), has a square bottom surface with P/6 as the length

of one side, takes H as the height, and has such a shape

that the permanent magnet module 52S is divided into four

equal parts by two planes respectively parallel to two

15   side-surfaces of the permanent magnet module 52S.  This

permanent magnet module 53S comprises two of permanent

magnet 58S having the shape of a wedge shown in Fig. 4(H).

Such a permanent magnet 58S has such a shape that the

permanent magnet 57S is divided into two equal parts by a

20   plane perpendicular to its bottom surface and N pole

surface.

     The permanent magnet module 54N, as shown in Fig.

5(A), has a rectangular bottom surface with P/3 as the

length of its long side and with P/6 as the length of its

25   short side, takes H as the height, and has such a shape

that the permanent magnet module 52N is divided into two

equal parts by a plane parallel to its side-surface.

This permanent magnet module 54N comprises one permanent

magnet 57N and two permanent magnets 58N's. Furthermore, the permanent magnet module 54S, as shown in Fig. 5(B), has a rectangular bottom surface with P/3 as the length of its long side and with P/6 as the length of its short side, takes H as the height and has such a shape that the permanent magnet module 52S is divided into two equal parts by a plane parallel to its side-surface. This permanent magnet module 54S comprises one permanent magnet 57S and two permanent magnets 58S's.

The permanent magnet 55, as shown in Fig. 5(C), is in the shape of a rectangular solid having a square bottom surface with P/3 as the length of one side and taking H as the height, and has two side-surfaces as a pair opposite with each other, of which one is N-pole surface and the other is S-pole surface. Furthermore, the permanent magnet 56, as shown in Fig. 5(D), is in the shape of a rectangular solid having a rectangular bottom surface with P/3 as the length of one side and P/6 as the length of the other side and taking H as the height, and has two side-surfaces as a pair opposite, in the long-arm direction, with each other of which one is N-pole surface and the other is S-pole surface.

The magnetic pole unit 51 is so structured that the bottom surfaces of the permanent magnet modules (52N, 52S, 53N, 53S, 54N, 54S) and the permanent magnets 55, 56 are arranged in one plane to form the arrangement shown in Fig. 3 in a planar view. Incidentally, the permanent magnets 55, 56 are so disposed that their magnetic-pole

surfaces have polarity opposite from the respective magnetic-pole surfaces of the permanent magnet modules 52N, 52S, 53N, 53S, 54N, 54S, which are opposite with those surfaces.

5      As described above, the driving magnetic pole unit 51 is structured by combining the permanent magnets magnetized in other directions than Z axis and no yoke material is used. Therefore, the driving magnetic pole unit 51 as a mover is lightweight.

10     The arrangement of the polarity of the respective permanent magnets in the driving magnetic pole unit 51 composed according to the above description is shown in Fig. 6. Fig. 6(A) shows a planar view of the arrangement of the polarity of the respective permanent magnets in 15 the driving magnetic pole unit 51, Fig. 6(B) shows the arrangement of the polarity of the respective permanent magnets which is seen by looking at the driving magnetic pole unit 51 in Fig. 6(A) from the below, and Fig. 6(C) shows the arrangement of the polarity of the respective 20 permanent magnets in the A-A cross section of Fig. 6(A). Incidentally, Fig. 6(B) and Fig. 6(C) show the arrangement in X-axis direction of the polarity of the respective permanent magnets, meanwhile the same arrangement is true in Y-axis direction as well.

25     The driving magnetic pole unit 51 has an air slider, not shown, (aero-hydrostatic bearing) fastened on itself, and has the substrate table 18 attached in its upper surface via a supporting mechanism (not shown). In the

air slider, a pressured air supplied via a connected air
tube from a air pump (not shown) is blew towards the
upper surface of the base 21, and the substrate table 18
with the magnetic pole unit 51 is levitated and supported

5    by a static pressure (so-called pressure inside the gap)
of the air layer between the upper surface of the base 21
and the driving magnetic pole unit 51.

As shown in Fig. 7, partially-broken-out section
including the supporting unit 40, the base 21 including

10   the stator 60 comprises a rectangular-shaped container 69,
in a planar view, which is shaped like a two-stepped
concave and is open in the upper side; a flat-plate-like
shaped magnetic member 62 made of a material such as
ferrite stainless or carbon steel, fastened to the step

15   portion in the bottom of this container 69 from the above,
and attached in the center portion of the height; and a
flat-plate-like shaped member 68 made of a non-magnetic
and non-conductive material such as ceramic or the like,
and attached so that the upper side of the container 69

20   is closed.

On the upper side surface of the magnetic member 62,
a plurality of armature coils 63's are disposed.  As an
armature unit, the flat-plate-like shaped coil module 61
is composed of these plurality of armature coils 63's,

25   and the stator 60 of the planar motor 50 is composed of
the flat-plate-like shaped coil module 61 and the
magnetic member 62.  The arrangement of armature coils
63's composing the flat-plate-like shaped coil module 61

is described later.

Incidentally, to prevent the temperature increase of the armature coils 63's and other members near them and the fluctuation of the ambient atmosphere of the armature

5    coils 63's, which is due to heat-generation caused by current supply to the armature coils 63's, cooling of the armature coils 63's is performed.  Such cooling is realized by making a closed space surrounded by the flat-plate-like shaped member 68, the container 69, and the

10   magnetic member 62 to be a path for a coolant to cool the armature coils 63's of the flat-plate-like shaped coil module 61.  Therefore, an inlet opening (not shown) is set on one side of the closed space and an outlet opening (not shown) is set on another side of the close space.  A

15   coolant (for example, water or FLUORINERT (product name of Sumitomo-3M Corp.) is sent into the closed space through the inlet opening from a cooling control mechanism (not shown) and heat-exchange with the flat-plate-like shaped coil module 61 is performed upon

20   passing the inside of the closed space, thereby the coolant heated up by the absorption of the heat generated in the flat-plate-like shaped coil module 61 is sent out of the outlet opening.

The flat-plate-like shaped coil module 61 is

25   composed of a plurality of the armature coils 63's arranged in the shape of a matrix as shown in Fig. 8(A), planar view, along with the reaction canceling magnetic pole unit 45X1, 45X2, 45Y1, 45Y2.  This armature coil 63

is, as shown in Fig. 8(B), in the shape of a rectangular

solid having an almost-square bottom surface with P as

the length of one side (parallel to X-Y plane) and having

a hole in Z direction around the center axis CX parallel

5    to Z-axis.  The cross section of the hole has the shape

of a square with P/3 as the length of one side.  The

current driving unit 22 supplies a current via terminals

64a and 64b for the armature coil 63 and the current

flows in almost uniform current density including its

10   inside around the center axis CX.  Incidentally, the

value and direction of current flowing the armature coil

63 is controlled via the current driving unit 22 by the

stage control system 19 and this control is executed for

each armature coil 63.

15   Furthermore, in Fig. 8(A), the armature coils 63's have

the same structure and armature coils on the four corner

opposite with the reaction canceling magnetic pole unit

45X1, 45X2, 45Y1, 45Y2 are particularly shown as armature

coils 63C1, 63C2, 63C3, 63C4.

20        The reaction canceling magnetic pole unit 45X1 is,

as shown in Fig. 9(A), composed of a supporting member 46,

a flat-plate-like shaped magnetic member 47 made of a

material such as ferrite stainless or carbon steel, and

two permanent magnets 48N, 48S.  Incidentally, Fig. 9(A)

25   is drawn upside down for the convenience.

     The supporting member 46, as shown in Fig. 9(A), Fig.

2, and Fig. 8(A), comprises a L-letter-like shaped flat

plate portion almost parallel to the flat-plate-like

shaped member 68, which is placed on the flat-plate-like

shaped member 68; a first column expanding vertically and

downwards from one end of the L-letter-like shaped flat

plate portion; a second column expanding vertically and

5    downwards from the other end of the L-letter-like shaped

flat plate portion; a first fixing portion set in the

bottom end of the first column; and a second fixing

portion set in the bottom end of the second column.  And

the supporting member 46 is fixed on a floor

10   independently from the supporting member 40 in the first

and second fixing portions.  Therefore, the reaction

canceling magnetic pole unit 45X1 is mechanically

independent from other members composing the exposure

apparatus 100.

15        Referring back to Fig. 9(A), the flat-plate-like

shaped magnetic member 47 has the shape of a square with

P as the length of one side in a planar view and is fixed

by screws, adhesive, etc. in the edge of the L-letter-

like shaped flat plate portion of the supporting member

20   46, which is on the surface opposite with the flat-plate-

like shaped member 68.

The permanent magnets 48N, 48S have the shape of a

square with P/3 as the length of one side in a planar

view, are arranged along X-axis direction in the surface

25   of the flat-plate-like shaped magnetic member 47 opposite

with the flat-plate-like shaped member 68, and are fixed

by screws, adhesive, or the like.  In the permanent

magnet 48N, the surface opposite with the flat-plate-like

shaped member 68 is N pole, and in the permanent magnet 48S, the surface opposite with the flat-plate-like shaped member 68 is S pole. These permanent magnets 48N, 48S are, as shown in Fig. 9(B), disposed opposite with each

5    other around the center of armature coil 63C1's current path, that is, the winding with respect to Y-axis direction.

The reaction canceling magnetic pole unit 45X2 has the same structure as the reaction canceling magnetic

10   pole unit 45X1, and the reaction canceling magnetic pole unit 45Y1, 45Y2 are composed in the same manner as the reaction canceling magnetic pole unit 45X1 except for permanent magnets 48N, 48S being arranged in Y-axis direction.

15   In the exposure apparatus 100 according to the present embodiment, as shown in Fig. 10, the reticle R is illuminated in a rectangular (or slit-like) illumination area IAR of which the longitudinal direction is perpendicular to the scanning direction (Y-axis

20   direction) of the reticle R. The reticle R is scanned at a speed $V_R$ in the (-Y) direction upon exposure. The illumination area IAR (the center of which almost coincides with the optical axis AX) is projected onto the wafer W via the projection optical system PL. A slit-

25   shaped projection area, which is conjugate with the illumination area IAR, that is, the exposure area IA, is formed. The wafer W and the reticle R have an inverted image forming relationship. The wafer W is, thus scanned

at a velocity $V_W$ synchronously with the reticle R in the direction opposite to the scanning direction of the reticle R, allowing the entire shot area SA on the wafer W to be exposed. The velocity ratio $V_W/V_R$ of the scanning

5  speed precisely corresponds to the reduction ratio of the projection optical system PL, and the pattern of the pattern area PA of the reticle R is accurately reduced and transferred onto the shot area SA on the wafer W. The width in the longitudinal direction of the

10  illumination area IAR is determined so as to be wider than that of the pattern area PA on the reticle R and to be narrower than the maximum width of the area including the shielding area ST. And by scanning the reticle R, the entire pattern area PA is illuminated.

15  Hereinafter, the operation of each part of the embodiment during the time when the wafer W is moving will be described. Firstly, the movement of the wafer W in this embodiment, that is, the outline of the principle of driving of the driving magnetic pole unit 51, as a

20  mover, of the planar motor 50, will be described by referring to Fig. 11 to 13.

In the driving magnetic pole unit 51, as shown by solid arrows in Fig. 11(A) representatively illustrating the case concerning the permanent magnet modules 52N, 52S,

25  the permanent magnet modules 52N, 53N, 54N generate magnetic fluxes in the (-Z) direction (downwards in the figure) and the permanent magnet modules 52S, 53S, 54S generate magnetic fluxes in the (+Z) direction (upwards

in the figure). And these permanent magnet modules

compose a magnetic circuit together with the permanent

magnets 55, 56, and the magnetic member 62. Incidentally,

in composing the magnetic circuit, the magnetic member 62

5    is used in all magnetic circuits, the permanent magnet 55

is used in a magnetic circuit concerning the permanent

magnet modules 52N and 52S, and the permanent magnet 56

is used in a magnetic circuit concerning the permanent

magnet modules 54N and 54S. Furthermore, the permanent

10   magnet 55 is used in a magnetic circuit concerning the

permanent magnet modules 52N and 54S (or 52S and 54N),

and the permanent magnet 56 is used in a magnetic circuit

concerning the permanent magnet modules 53N and 54S (or

53S and 54N).

15       In the following, a magnetic circuit concerning the

permanent magnets 52N, 52S will be described as an

example.

In a magnetic circuit shown in Fig. 11(A), a

magnetic flux density B around the magnetic member 62,

20   that is, in Z position where the flat-plate-like shaped

coil module 61 is placed, takes a distribution shown in

Fig. 11(B). That is, the absolute value of the magnetic

flux density B is maximum in positions corresponding to

the center points of the permanent magnet modules 52N,

25   52S, decreases as going from the center points to the

periphery of the permanent magnet modules 52N, 52S

respectively, and takes zero at the middle between the

position corresponding to the center point of the

permanent magnet module 52N and the position

corresponding to the center point of the permanent magnet

module 52S.  Furthermore, the distribution of the

magnetic flux density B is symmetric in (±)X direction

5    with the positions corresponding to the center points of

the permanent magnet modules 52N, 52S as centers.  That

is, the X-directional distribution of the magnetic flux

density B is such that it can be approximated by a sine

function or trapezoidal function.  Incidentally, in Fig.

10    11(B), when the direction of the magnetic flux is (+Z)

direction, the value of the magnetic flux density B takes

positive, and when the direction of the magnetic flux is

(-Z) direction, the value of the magnetic flux density B

takes negative.  Furthermore, the same distribution as

15    the X-directional distribution of the magnetic flux

density B that Fig. 11(B) shows is true in Y direction as

well.

Incidentally, in the present embodiment, as a

material for magnetic members, for example, ferrite

20    stainless, carbon steel, or the like which is of high

resistance, high saturation magnetic flux density, low

magnetic hysteresis, and low coercive force is used,

thereby it is possible to decrease eddy currents,

hysteresis losses, and magnetic resistance and

25    successively generate a magnetic flux of high magnetic

flux density even when the driving magnetic pole unit 51

is moving.

In the following, the driving of the mover 51 by

Lorentz force generated by an interaction between a magnetic flux, between the driving magnetic pole unit 51 and the magnetic member 62, and a current flowing the armature coil 63 will be described.

5     Under the environment of the magnetic flux density B having the distribution shown in Fig. 11(B), when a current is supplied to the armature coil 63, a Lorentz force is generated in the armature coil 63. The magnitude and direction of the Lorentz force vary

10     depending on a positional relation between the driving magnetic pole unit 51 and the flat-plate-like shaped coil module 61. Assume that, firstly, the positional relation between the driving magnetic pole unit 51 and the flat-plate-like shaped coil module 61 is a positional relation,

15     shown in Fig. 12(A), among armature coils $63_1$, $63_2$, $63_3$, $63_4$, ..., permanent magnets $52N_1$, $52N_2$, ..., and permanent magnets $52S_1$, $52S_2$, ... to consider the Lorentz force. Incidentally, in Fig. 12(A), the armature coils $63_1$, $63_2$, $63_3$, $63_4$ are drawn by solid lines and the permanent magnets

20     $52N_1$, $52N_2$, $52S_1$, $52S_2$ are drawn by dashed lines.

    That is, assume that the armature coils $63_1$, $63_2$, $63_3$, $63_4$ are sequentially arranged in X direction and the permanent magnets $52N_1$, $52N_2$, $52S_1$, $52S_2$ are sequentially arranged along X0-axis parallel to X direction.

25     Furthermore, assume that, in Fig. 12(A), the left edge of the armature coil $63_1$ and the left edge of the permanent magnets $52N_1$ are apart from each other by a distance $\Delta X$.

    In such a arrangement-relation, pay attention to

points Q1, Q2, Q3, Q4 in the armature coils $63_1$, $63_2$, $63_3$, $63_4$, shown in Fig. 12(B), which are along X1-axis parallel to the X0-axis. Furthermore, assume that, as illustrated in Fig. 12(A), the X0-axis and the X1-axis are apart from each other by a distance $\delta Y$ in Y direction, the point Q1 and the point Q2 are apart from each other by a distance P in X direction, and the point Q3 and the point Q4 are apart from each other by a distance P in X direction.

When the driving magnetic pole unit 51 has moved in X direction, that is, the distance $\Delta X$ changes, a magnetic flux density $B_1$ ($\Delta X$; $\delta Y$) in the point Q1 changes in a way shown by a solid line in Fig. 13(A). Such a change is the same as in Fig. 11. Now, assuming the distribution in the Fig. 11 to be well approximated by a sine function, the magnetic flux density $B_1$ ($\Delta X$; $\delta Y$) is given by

$$B_1 \ (\Delta X; \ \delta Y) = B_0 \ (\delta Y)$$
$$\times \ \sin \ \{(3\pi/2P) \ \Delta X + \phi\} \ \cdots (1).$$

The value $\phi$ is a constant determined by X position of the point Q1, $B_0$ ($\delta Y$) is a constant determined according to $\delta Y$.

Furthermore, when the driving magnetic pole unit 51 has moved in X direction, that is, the distance $\Delta X$ changes, a magnetic flux density $B_2$ ($\Delta X$; $\delta Y$) in the point Q2 changes in a way shown by a dashed line in Fig. 13(A). Now, assuming the distribution to be well approximated by a sine function, the magnetic flux density $B_2$ ($\Delta X$; $\delta Y$) is given by

$$B_2 \ (\Delta X; \ \delta Y) = -B_0 \ (\delta Y)$$
$$\times \ \cos \ \{(3\pi/2P) \ \Delta X + \phi\} \ \cdots (2).$$

$B_2$ ($\Delta X$; $\delta Y$) is obtained by shifting $B_1$ ($\Delta X$; $\delta Y$) in X direction by 1/4 of the period.

When supplying a current $I_1$ ($\Delta X$; $\delta Y$) shown by a solid line in Fig. 13(B) and given by

$$I_1 (\Delta X) = I_0 \sin \{(3\pi/2P) \Delta X + \phi\} \quad \cdots (3)$$

for the armature coil $63_1$, and supplying a current $I_2$ ($\Delta X$; $\delta Y$) shown by a dashed line and given by

$$I_2 (\Delta X) = - I_0 \cos \{(3\pi/2P) \Delta X + \phi\} \quad \cdots (3)$$

for the armature coil $63_2$, assuming that $I_1$ ($\Delta X$) flows only in Y-axis direction in the point Q1 and $I_2$ ($\Delta X$) flows only in Y-axis direction in the point Q2, the X-component FX1 ($\Delta X$; $\delta Y$) of Lorentz force per a unit-length generated in the point Q1 shown in Fig. 12(B) is given by

$$FX1 (\Delta X; \delta Y) = B_1 (\Delta X; \delta Y) \times I_1 (\Delta X) \quad \cdots (5),$$

and the X-component FX2 ($\Delta X$; $\delta Y$) of Lorentz force per a unit-length generated in the point Q2 shown in Fig. 12(B) is given by

$$FX2 (\Delta X; \delta Y) = B_2 (\Delta X; \delta Y) \times I_2 (\Delta X) \quad \cdots (6).$$

Then, the resultant force, F ($\delta Y$), of FX1 ($\Delta X$; $\delta Y$) and FX2 ($\Delta X$; $\delta Y$) is given by

$$F (\delta Y) = B_0 (\delta Y) \times I_0 \quad \cdots (7).$$

That is, also when the driving magnetic pole unit 51 moves, the resultant force from the X-component of Lorentz force per a unit-length in the point Q1 and the X-component of Lorentz force in the point Q2 is constant independently of the X-position of the driving magnetic pole unit 51, that is, the distance $\Delta X$ as shown in Fig. 13(C).

In the above description, it was assumed that all currents flow in Y-axis direction in the points Q1 and Q2. However, currents in the points Q1 and Q2 can have a X-component. In such a case, considering that the

5 directions of currents in the points Q1 and Q2 are parallel to each other due to the periodicity of the arrangement of the armature coils 63's, by supplying currents different from each other in phase by 1/4 of the period to the armature coils $63_1$, $63_2$, the X-component of

10 the resultant force from the Lorentz force per a unit-length in the point Q1 and the Lorentz force in the point Q2 is constant independently of the X-position of the driving magnetic pole unit 51.

Furthermore, the selection of the point Q1 in the

15 armature coil $63_1$ is arbitrary and the point Q2 corresponding to the point Q1 is uniquely determined in the armature coil $63_2$ by all means. Accordingly, by controlling the current $I_1$ ($\Delta X$) supplied to the armature coil $63_1$ and the current $I_2$ ($\Delta X$) supplied to the armature

20 coil $63_2$ to respectively satisfy the equations (3) and (4), the X-component of the resultant force from the Lorentz force generated in the armature coil $63_1$ and the Lorentz force in the armature coil $63_2$, can be constant independently of the X-position of the driving magnetic

25 pole unit 51. Incidentally, the magnitude of X-component of the resultant force can be controlled by changing the value $I_0$ in the equations (3) and (4).

When exchanging the points Q1, Q2 with the points Q3,

Q4, it is easy to understand that also when applying the same current-control as the armature coils $63_1$, $63_2$ to the armature coils $63_3$, $63_4$, the X-component of the resultant force of the Lorentz forces can be controlled to be

5  constant independently of the X-position of the driving magnetic pole unit 51 in the same manner as in the armature coils $63_1$, $63_2$.  Incidentally, the amount of X-component of the resultant force can be controlled by changing the value $I_0$ in the equations (3) and (4).

10  Furthermore, when applying the same current-control as the armature coils $63_1$, $63_2$ to any two armature coils 63's adjacent to each other, the X-component of the resultant force of the Lorentz forces can be controlled to be constant independently of the X-position of the driving

15  magnetic pole unit 51.

Therefore, by selecting a pair of two armature coils adjacent to each other in X direction according to the X-position of the driving magnetic pole unit 51 and controlling the currents of each pair of the armature

20  coils 63's to satisfy the equations (3) and (4), the driving magnetic pole unit 51 can be driven in X direction by a arbitrary and constant driving force independently of the X-position of the driving magnetic pole unit 51.

25  Incidentally, considering a pair of the armature coils 63's, when supplying currents to drive the driving magnetic pole unit 51 in X direction, generally a force to drive the driving magnetic pole unit 51 in Y direction

and a torque around Z-axis are generated. Therefore, the current of each armature coil 63 is so adjusted that a force to drive the driving magnetic pole unit 51 in Y direction and a torque become zero as a whole.

5       Furthermore, in the above, a case where X-directional distribution of a magnetic flux density B around the flat-plate-like shaped coil module 61 is well approximated by a sine function is described, however, if such an approximation is not appropriate, instead of the

10   equations (3) and (4), the currents $I_1$ ($\Delta X$), $I_2$ ($\Delta X$) supplied to the armature coils $63_1$, $63_2$ can be determined by using the following equations:

$$I_1 \, (\Delta X) = C_0 \, \sin^2 \{(3\pi/2P) \, \Delta X + \phi\}/ \, B_1 \, (\Delta X; \, \delta Y) \quad \cdots (8)$$

$$I_2 \, (\Delta X) = C_0 \, \cos^2 \{(3\pi/2P) \, \Delta X + \phi\}/ \, B_2 \, (\Delta X; \, \delta Y) \quad \cdots (9).$$

15   $C_0$ is a constant.

      Using these equations, the resultant force, F ($\delta Y$), of FX1 ($\Delta X$; $\delta Y$) and FX2 ($\Delta X$; $\delta Y$) is given by

$$F \, (\delta Y) = C_0 \, (\delta Y) \qquad\qquad\qquad \cdots (10).$$

That is, also when the driving magnetic pole unit 51, the

20   X-component of the resultant force from the Lorentz force generated in the point Q1 and the Lorentz force in the point Q2 can be constant.

      In the above case where the driving magnetic pole unit 51 moves in X direction, the X-directional drive of

25   the driving magnetic pole unit 51 is described. Also about the Y-directional drive of the driving magnetic pole unit 51, the driving magnetic pole unit 51 can be driven by a constant driving force in Y direction

independently of the Y-position of the driving magnetic pole unit 51 in the same manner as in X direction.  That is, by adaptively selecting a pair of two armature coils 63's adjacent to each other in Y direction and

5    controlling currents according to similar equations to the equations (3) and (4), or the equations (8) and (9), besides, by controlling currents so that the driving force to drive the driving magnetic pole unit 51 in X direction becomes zero and the torque of the driving

10   magnetic pole unit 51 is cancelled as a whole, the driving magnetic pole unit 51 can be driven by a constant driving force in Y direction independently of the Y-position of the driving magnetic pole unit 51.

     Furthermore, by supplying a current having a pattern,

15   which is obtained by superposing a current-pattern of X-directional drive on a current-pattern of Y-directional drive with an appropriate rate, to each armature coil 63, the driving magnetic pole unit 51 can be driven in any direction on X-Y plane by a driving force having an

20   arbitrary magnitude.

     Furthermore, by driving the driving magnetic pole unit 51 without canceling the torque, the driving magnetic pole unit 51 can be rotationally driven in a desired direction by a desired torque.

25   Therefore, according to the planar motor 50 of the present embodiment, making use of the advantages of the Lorentz force method that is excellent in controllability, linearity of thrust, and positioning accuracy, the light-

weight driving magnetic pole unit 51 can be driven in any direction on X-Y plane by a driving force having an arbitrary magnitude.

In the stage unit 30 of the present embodiment, as described above, the substrate table 18 that holds a wafer W via the wafer holder 25 is attached to the driving magnetic pole unit 51. Thus, by controlling the drive of the driving magnetic pole unit 51 via the stage controller 19 as described above, the main controller 20 can move the substrate table 18 and the wafer W integrally with the driving magnetic pole unit 51 freely on the X-Y plane. More specifically, when the driving magnetic pole unit, that is, the substrate table 18 is moved in a desired direction by using a desired thrust, the main controller 20 monitors the measurement values of the wafer interferometer 31 (positional information or the velocity information) via the stage control system 19, and obtains the relative-position relationship between the mover 51 and the stator within the X-Y plane. And the main controller 20 calculates and determines the value and direction of a current to be supplied to each armature coil 63 in accordance with the obtained relative-position information and the target position to which the substrate table 18 is to be driven, and then the main controller 20 sends instructions to the stage control system 19. Consequently, the stage control system 19 controls the value and direction of the electric current to be supplied to each armature coil 63

via the current driving unit 22 (not shown). In this case, the main controller 20 also controls the speed of the substrate table 18 in accordance with the distance to the target position.

5      The main controller 20 may calculate the value and direction of the current to be supplied to each armature coil 63, at each time-point of move, according to the positional information (or velocity information) sent by the wafer interferometer 31. However, if its control

10     response time is not short enough, the main controller 20 may calculate the value and direction of the current to be supplied to each armature coil 63 correspondingly to the passage of time, that is, the move of the mover 51 at the start of the move so that the wafer W takes a desired

15     locus and speed in a certain subsequent time-period. In this case, the main controller 20 calculates the deviation of the wafer W from the desired locus based on the positional information (or velocity information) sent from the wafer interferometer 31, corrects the value and

20     direction of the current to be supplied to each armature coil 63, and calculates the value and direction of the current for a predetermined time-period subsequent to the correction in time series. Then, the stage system 19 controls the current of each armature coil 63 according

25     to the corrected information.

In the present embodiment, in the drive of the driving magnetic pole unit 51, the stage control system 19 detects the armature coil 63 opposite with the driving

magnetic pole unit 51 according to the positional

information (or velocity information) sent from the wafer

interferometer 31 and controls the current driving unit

22 so that the current to drive the driving magnetic pole

5    unit 51 is supplied only to that armature coil 63.

Therefore, because the current is not supplied to an

armature coil 63 to generate no or weak Lorentz force,

the current consumption can be efficiently reduced

maintaining the driving force.

10       Next, concerning the present embodiment, an outline

about the principle of canceling of the reaction acting

on the stator 60 will be described referring to Fig. 14

to Fig. 16.

In the reaction canceling magnetic pole unit 45X1,

15   as shown by solid arrows in Fig. 14(A), the permanent

magnet 48N generates a magnetic flux in (-Z) direction

(downwards in the Fig.), and the permanent magnet 48S

generates a magnetic flux in (+Z) direction (upwards in

the Fig.). And a magnetic circuit in which the magnetic

20   flux flows sequentially in the permanent magnet 48N, the

magnetic member 62, the permanent magnet 48S, and the

magnetic member 47 is formed.

In this case, around the upper surface of the

magnetic member 62, that is, Z position where a armature

25   coil 63C1 being one of the armature coils 63's

constituting the flat-plate-like shaped coil module 61 is

placed, the magnetic flux density B takes a distribution

shown in Fig. 14(B). That is, the absolute value of the

magnetic flux density B is maximum at positions corresponding to the centers of the permanent magnets 48N, 48S, and as going out from the positions to positions corresponding to the peripheries of the permanent magnets, the absolute value of the magnetic flux density B decreases. Then at the middle between the position corresponding to the center of the permanent magnets 48N and the position corresponding to the center of the permanent magnets 48S, the absolute value of the magnetic flux density B takes zero. Furthermore, the distribution of the magnetic flux density B is point-symmetric with the positions corresponding to the center points of the permanent magnet modules 48N, 48S as centers.

Incidentally, in Fig. 14(B), the value of the magnetic flux density B is positive when the direction of the magnetic flux is (+Z) direction and the value of the magnetic flux density B is negative when the direction of the magnetic flux is (-Z) direction.

Moreover, at Z position where a armature coil 63C1 is placed, the reaction canceling magnetic pole unit 45X1 generates the same magnetic flux density B as in Fig. 14(B).

Furthermore, at Z positions where armature coils 63C2, 63C4 are placed, the reaction canceling magnetic pole units 45Y1, 45Y2 generate a magnetic flux density B of which the distribution has the X-direction in Fig. 14(B) changed to Y-direction.

Under the environment of a magnetic flux density B

having the distribution shown in Fig. 14(B), when a left-handed current IX1, in a planar view, shown in Fig. 15(A) is supplied to the armature coil 63C1, by an electromagnetic interaction, a Lorentz force $FCX1_1$ is generated

5   in (+X) direction in an opposite portion of the armature coil 63C1 with the permanent magnet 48N and a Lorentz force $FCX1_2$ is generated in (+X) direction in an opposite portion of the  armature coil 63C1 with the permanent magnet 48S.  Consequently, the resultant force of the

10  Lorentz force $FCX1_1$ and $FCX1_2$ acts on the armature coil 63C1 in (+X) direction, and is applied to the stator.  In this way, the force FCX1 can be generated along the same plane as a plane along which the reaction acting on the stator 60 due to the drive of the magnetic pole unit 51,

15  that is, the Lorentz force generated in the armature coil 63 is.  Incidentally, the magnitude of the force FCX1 is proportional to the current IX1.

Moreover, when a right-handed current IX1, in a planar view, shown in Fig. 15(B) is supplied to the

20  armature coil 63C1, by an electromagnetic interaction, a Lorentz force $FCX1_1$ is generated in (-X) direction in an opposite portion of the armature coil 63C1 with the permanent magnet 48N and a Lorentz force $FCX1_2$ is generated in (-X) direction in an opposite portion of the

25  armature coil 63C1 with the permanent magnet 48S. Consequently, the resultant force of the Lorentz force $FCX1_1$ and $FCX1_2$ acts on the armature coil 63C1 in (-X) direction, and is applied to the stator.

That is, by controlling the direction and magnitude of the current supplied to the armature coil 63C1, the force FCX1 of a desired magnitude in a desired direction, (+X) or (-X) direction, is applied to the placement-
5   position of the armature coil 63 C1 of the stator 60.

Moreover, also in the armature coil 63C3, in the same manner as the armature coil 63C1, by controlling the direction and magnitude of the current supplied to the armature coil 63C3, the force FCX2 of a desired magnitude
10   in a desired direction, (+X) or (-X) direction, is applied to the placement-position of the armature coil 63C3 of the stator 60 (refer to Fig. 16).

Furthermore, also in the armature coil 63C2, 63C4, in the same manner as the armature coil 63C1, by
15   controlling the directions and magnitudes of the current supplied to the armature coils 63C2, 63C4, the forces FCY1, FCY2 of a desired magnitude in a desired direction, (+X) or (-X) direction, are applied to the respective placement-positions of the armature coils 63C2, 63C4 of
20   the stator 60 (refer to Fig. 16).

Incidentally, as shown in Fig. 16, when the driving magnetic pole unit 51 is driven by a force F, a reaction (-F) acts on point R of the stator. Now, represent the X-component of the reaction (-F) by (-FX), the Y-
25   component of the reaction (-F) by (-FY), and the distance between a line along which the reaction (-F) is and the gravity center G of the stator 60 by D.

To cancel such a reaction, representing the X-

components of the forces FCX1, FCX2 by CX1, CX2, the Y-components of the forces FCY1, FCY2 by CY1, CY2, and the magnitude of the reaction by F, then, forces FCX1, FCX2, FCY1, FCY2 given by the following equations should be

5    applied:

$$FX = CX1 + CX2 \qquad \cdots(11)$$

$$FY = CY1 + CY2 \qquad \cdots(12)$$

$$F \cdot D = CX1 \cdot LY1 - CX2 \cdot LY2$$
$$+ CY1 \cdot LX1 - CY2 \cdot LX2 \qquad \cdots(13).$$

10   Incidentally, the Y-directional distances between the gravity center G and the respective points where the forces FCX1, FCX2 are applied are represented by LY1, LY2 and the X-directional distances between the gravity center G and the respective points where the forces FCY1,

15   FCY2 are applied are represented by LX1, LX2.

In the above equations (11) to (13), because the number of unknown variables (CX1, CX2, CY1, CY2) is four and the number of the equations is three, a solution can be found.  By choosing a group of FCX1, FCX2, FCY1, FCY2

20   satisfying the equations (11) to (13) and supplying currents to generate them to the armature coils 63C1, 63C2, 63C3, 63C4, the reaction acting on the stator 60 due to the drive of the driving magnetic pole unit 51 can be cancelled.  Incidentally, the exposure apparatus 100

25   of the present embodiment chooses one that makes the total amount of supply-currents smaller out of groups of FCX1, FCX2, FCY1, FCY2 satisfying the equations (11) to (13).

In the exposure apparatus 100 of the present
embodiment, the main control unit 20, via the stage
control system 19 and the current driving unit 22, drives
the driving magnetic pole unit 51 by supplying the

5    current to the armature coil 63 opposite with the driving
magnetic pole unit 51 as described above, and
simultaneously cancels the reaction that is known to
itself and acts on the stator 60 by applying the forces
FCX1, FCX2, FCY1, FCY2 that are generated by the

10   electromagnetic interaction and satisfy the equations
(11) to (13). Accordingly, because the force to
accurately cancel the reaction is applied to the stator
60 with no delay-time from the act of the reaction, the
reaction acting on the stator 60 due to the drive of the

15   driving magnetic pole unit 51 can be very accurately
cancelled.

Incidentally, in the above, the cancellation of the
reaction in the translational drive is described. In the
case of a rotational drive, two kinds of reactions act on

20   the stator 60. In this case, the entire reaction can be
cancelled by calculating forces to cancel the respective
reactions and applying the resultant force of those
forces to the stator.

Moreover, the reaction canceling magnetic pole units

25   45X1, 45X2 45Y1, 45Y2 are fixed on a floor, etc. via the
respective supporting members 46's independently of the
stator and the other elements of the exposure apparatus
100. Therefore, although, when applying the forces FCX1,

FCX2, FCY1, FCY2 to the stator 60 to cancel the reaction acting on the stator due to the drive of the driving magnetic pole unit 51, reactions against those forces come to act on the reaction canceling magnetic pole units

5    45X1, 45X2 45Y1, 45Y2, the reactions do not cause the vibration of the stator 60, the supporting member 40, and the like. Therefore, positional information (or the velocity information) detected by the reticle interferometer 16 fixed on the supporting member and the

10   wafer interferometer 31 does not include the effect of the drive of the driving magnetic pole unit 51.

     Next, the brief description of the flow of a exposure operation in the exposure apparatus 100 including the aforementioned stage unit will be presented.

15    First, a reticle R, on which a pattern to be transferred is formed, is loaded onto the reticle stage RST by a reticle loader. Similarly, a wafer W to be exposed is loaded onto the substrate table 18 by a wafer loader.

20    At this point, the substrate table 18 is supported by air levitation at a predetermined wafer loading position on the base 21. The main controller 20 servo-controls the substrate table 18 via the stage system 19 based on the measurement value of the wafer

25    interferometer, so that the substrate table 18 stays positioned at the loading position for a predetermined period of time. When the substrate table 18 is staying at the loading position, the electric current is supplied

to each armature coil 63 of the stator 60 of the planar

motor 50.  Accordingly, the main controller 20 cools each

armature coil 63 via a cooling device, etc. so as to

prevent the temperature of the armature coil 63 from

5    rising due to the generated heat.

Next the main controller 20 prepares for a reticle

alignment and a base line measurement in a predetermined

procedure, by using what is called a reticle microscope

(not shown), a reference mark plate (not shown in Figs.)

10   mounted on the substrate table 18, and an alignment

detecting system (not shown).  And by using the alignment

detection system, alignment measurement such as EGA

(Enhanced Global Alignment) of which the details are

disclosed in the Japan Patent Laid Open No. 61-44429 and

15   the corresponding U.S. Patent No. 4780617 is performed.

During such operations, when the wafer W needs to be

moved, the main controller 20 controls the current

supplied to the each armature coil 63 within the stage

unit via the stage control system 19 and moves the mover

20   51 so as to move the wafer W.  Simultaneously with the

drive of the driving magnetic pole unit 51, the main

controller 20 controls the currents of the armature coils

63C1, 63C2, 63C3, 63C4 in the stage unit via the stage

control system, and cancels the reaction acting on the

25   stator 60 due to the drive of the driving magnetic pole

unit 51.  After completing such alignment measurement, a

step-and-scan exposure is performed, in the following

manner.  The disclosures, cited above are fully

incorporated by reference herein as long as the national
laws in designated states or elected states, to which
this international application is applied, permit.

Upon exposure, first of all, the substrate table 18

5      is moved so that the X-Y position of the wafer W is
positioned at a scanning starting position of the first
shot area (first shot). This movement is performed by
the main controller 20 controlling the current supplied
to each armature coil 63 (including the armature coils

10     63C1, 63C2, 63C3, 63C4) constituting the planar motor 50
via the stage control system 19, as described above.
Simultaneously, the reticle stage RST is moved so that
the X-Y position of the reticle is at a scanning starting
position. This movement is performed by the main

15     controller 20 via the stage control system 19 and the
reticle driving portion (not shown).

Then, the stage control system 19 synchronously
moves the reticle R and the wafer W via the reticle
driving portion (not shown) and the planar motor 50 while

20     canceling the reaction acting on the stator 60. This is
performed in accordance with the X-Y positional
information of the reticle R measured by the reticle
interferometer 16, and the X-Y positional information of
the wafer W, which is measured by the wafer

25     interferometer 31. With this synchronized movement of
the reticle and the wafer, scanning exposure is performed.

When the transfer of a reticle pattern onto a shot
area by scanning exposure controlled as described above

is completed, the substrate table 18 is stepped by a distance of one shot area. Then, scanning exposure is performed on the next shot area. Also in this stepping, the reaction acting on the stator 60 is cancelled

5    according to the X-Y positional information of the wafer W, which is measured by the wafer interferometer 31 while moving the wafer W by the planar motor 50.

The stepping operation and scanning exposure are repeatedly performed in sequence, thus, transferring the

10   necessary number of patterns onto the wafer W. Therefore, with the exposure apparatus 100 according to this embodiment, by using the stage unit having the planar motor 50, the positioning of the wafer W can be achieved with high accuracy at a high speed. As a consequence,

15   the exposure with high exposure precision can be achieved, improving the throughput. That is, by having the exposure apparatus 100 of the present embodiment comprise the planar motor 50 and other elements such as the illumination system 10, the projection optical system PL,

20   etc. shown in Fig. 1, the exposure apparatus with high exposure precision and improved throughput can be realized.

Incidentally, according to this embodiment, the permanent magnets are disposed in the mover (driving

25   magnetic pole unit) and the reaction canceling magnetic pole unit, and the armature coils are disposed in the stator, however, it is possible that the armature coils are disposed in the mover (driving magnetic pole unit)

and the reaction canceling magnetic pole unit, and the permanent magnets are disposed in the stator.

Moreover, according to this embodiment, the mover is levitated from the stator by the air guide mechanism. However, also an electromagnetic levitation mechanism can be used. Moreover, electromagnets equivalent to permanent magnets can be used instead of the permanent magnets.

Furthermore, according to this embodiment, on each of the four corners of the stator, the reaction canceling magnetic pole units are placed, however, even if those are placed on three of the four corners, the reaction can be canceled. Moreover, even if, on any three or more points, the reaction canceling magnetic pole units to generate forces that are not in the same direction are placed, the reaction can be canceled.

Furthermore, in this embodiment, a liquid coolant is used for cooling the armature coils. However, as long as it is a fluid that can serve as a coolant, a gas coolant may be used.

Additionally, the number of the driving magnetic pole units 51's as a mover arranged on the stator is not limited to 1. For instance, as illustrated in Fig. 17, two driving magnetic pole units 51's may be arranged on a stator 60, then the two driving magnetic pole units can be driven independently so that the exposure of a wafer can be performed by using one driving magnetic pole unit 51, whereas having the other driving magnetic pole unit

51 to perform the delivery, etc. of the wafer. In such a
case, although two or more kinds of reactions act on the
stator, the reactions can be canceled by calculating
forces to cancel the respective reactions and applying

5  the resultant force of them to the stator similarly with
the embodiment described above.

Moreover, the stage unit 30 according to the
embodiment is applicable to the reticle stage RST. In
this case, the aforementioned reaction frame can be

10  omitted.

The exposure apparatus 100 according to the
embodiment can be made by having the reticle stage RST
comprising plenty of mechanical elements, the projection
optical system PL comprising a plurality of lenses, and

15  the base 21 mounted on the supporting member 40, having
other elements, such as the stage unit 30 and the
reaction canceling magnetic pole unit 45X, 45Y, than the
base 21 attached to the base 21, and having a
comprehensive adjustment (electric adjustment, function

20  confirmation, etc.) performed. Also, the base 21 may be
attached independently of the supporting member 40.

Incidentally, it is preferred that the making of the
exposure apparatus 100 is performed in a clean room where
the temperature, the degree of cleanness, etc. are

25  controlled.

Furthermore, the present invention can be applied to
all of wafer exposure apparatuses, liquid crystal
exposure apparatuses, etc. such as a reduced projection

exposure apparatus using ultraviolet light as its light source, a reduced projection exposure apparatus using a soft X-ray of which the wavelength is 10 nm or so as its light source, a reduced projection exposure apparatus

5    using X-rays of 1 nm or so in wavelength as its light source, an exposure apparatus using EB (Electron Beams) or ion beams.  Furthermore, the present invention may be applied to a step-and-repeat type apparatus, a step-and-scan type apparatus, and a step-and-stitch type apparatus.

10   However, in the case when this invention is applied to a reduced projection exposure apparatus using a soft X-ray of which the wavelength is 10 nm or so as its light source, a reduced projection exposure apparatus using X-rays of 1 nm or so in wavelength as its light source, an

15   exposure apparatus using EB (Electron Beams) or ion beams, where the surrounding environment of the wafer and the like need to be in vacuum, it is necessary to employ the magnetic levitation mechanism because the air guide mechanism can not be used as the levitation mechanism to

20   levitate the mover from the stator.

## INDUSTRIAL APPLICABILITY

As described above, the stage unit according to the present invention applies the force to cancel the

25   reaction acting on the stator due to the drive of the mover to the stator by the electromagnetic interaction and the mover is made light weight by composing the magnetic pole unit, that composes the mover, by combining

magnets having such magnetization-directions that their magnetic flux are toward the stator and magnets having magnetization-directions crossing the aforementioned magnetization-directions without using yoke material,

5   thereby the vibration of the stator can be prevented even upon the high speed drive of the mover.  Therefore, the stage unit is suitable for performing the highly precise positioning control while moving a placed sample.

Furthermore, the exposure apparatus according to the

10  present invention controls the position of the wafer, etc. accurately and at a high speed, therefore the exposure apparatus is suitable for highly accurate exposure.